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ABSTRACT

Emissions from heavy-duty vehicles are a major contributor to California's air quality problems. Emissions from these vehicles account for approximately 30% of the nitrogen oxide and 75% of the particulate matter emissions from the entire on-road vehicle fleet. Additionally, excessive exhaust smoke from in-use heavy-duty diesel vehicles is a target of numerous public complaints. In response to these concerns, California has adopted an in-use Heavy-Duty Vehicle Smoke and Tampering Inspection Program (HDVIP) designed to Significantly reduce emissions from these vehicles. Pending promulgation of HDVIP regulations, vehiclcs failing prescribed test procedures and emission standards will be issued citations. These citations mandate expedient repair of the vehicle and carry civil penalties ranging from $300 to $1800. Failure to clear citations can result in the vehicle being removed from service. It is projected that this program will reduce nitrogen oxide, hydrocarbon and particulate matter emissions from these vehicles by 19, 22 and 32 tons per day respectively at a cost effectiveness ranging from $0.44 to $0.47 per pound reduced.

INTRODUCTION

California experiences the nation's most severe air pollution problems. In 1989, California's South Coast Air Basin (greater Los Angeles region) exceeded the federal ambient ozone standard on more than 160 days, and the more restrictive state ambient ozone standard on more than 210 days. During 1989, peak ozone levels in this region were 0.34 parts per million (ppm), approximately three times the federal standard and four times the state standard. Heavy-duty diesel vehicles are a major contributor to this problem. The projected 1991 statewide exhaust emissions inventory for these vehicles Is: 107 tons per day (tpd) for hydrocarbons (HC), 123 tpd for particulate matter (PM), and 543 tpd for oxides of nitrogen (NOx) (1). Emissions from these vehicles are estimated to account for approximately 302 of the NOx and 76% of the PM emissions from the entire on-road vehicle fleet even though these vehicles only account for approximately 22 of the on-road vehicle fleet (Figure 1).

Diesel exhaust emissions are an obvious byproduct of diesel fuel combustion. The profile of diesel exhaust emissions varies significantly and is dependent upon such factors as engine type and aspiration; fuel grade and composition; engine temperature, speed and load; engine maintenance; and engine duty cycles. Diesel exhaust contains numerous compounds emitted in gaseous and solid (Particulate) phases. The gas phase contains a variety of compounds including carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxide and hydrocarbons. Hydrocarbon species include polycyclic aromatic hydrocarbons (PAHs) (e.g. benzo(a)pyrene, pyrene, etc.), olefins, ethylene, and propylene. The particulate phase omissions consist primarily of soot, sulfates, and high molecular weight hydrocarbons (PAHs). These PAHs tend to absorb or condense on the soot and account for approximately 16% to 66% of the diesel particulate mass. (2) Soot is a fine

dispersion of black particles composed of solid carbon cores produced during engine combustion. Soot particles tend to form cluster or chain aggregates. In general, soot accounts for approximately 50%of the total particulate mass.

Although no quantitative relationship has been demonstrated to date, it is widely held that reductions in heavy-duty diesel engine smoke emissions results in reductions of particulate and hydrocarbon emissions (3).

Numerous toxic compounds including: benzene, 1,3-Butadiene, benzo(a)pyrene, and formaldehyde have been identified in diesel exhaust and are generally determined to be constituents of the hydrocarbon portion of the exhaust stream. These toxic compounds, and diesel exhaust in and of itself, are being evaluated for identification as toxlc air contaminants under the California Air Resources Board's (ARB) Toxic Air Contaminant Program as mandated by California Assembly Bill 1807 of 1983 (4). Diesel exhaust has been listed as a probable human carcinogen by the International Agency for research on Cancer. The hydrocarbon and nitrogen oxide emissions from heavy-duty vehicles contribute to California's inability to meet federal and state ambient ozone standards resulting in increased public health Impacts, reductions in agricultural production, and other adverse environmental impacts. Diesel exhaust particulate matter is a major public concern because of its size (less than 10 microns in diameter and is referred to as PM 10) and role as a carrier for toxic compounds as discussed infra. During respiration, PM 10 is drawn deep into the respiratory tract leading to lund tissue damage and reduced pulmonary function. These particulate matter emissions also impair visibility and contribute to Callfornla's inability to federal and state ambient particulate standards. Additionally, excessive diesel engine exhaust smoke, primarily caused by engine tampering and malmaintenance, Is a target of numerous public complaints from concerned citizens.

In response to these concerns, the California Leglslaturr passed Senate Bill (SB) 1997 In 1988. This bill enhanced California's SmogCheck Program (I/M program) and added Section 44011.6 to the California Health and Safety Code (HLSC) which authorized the adoption of a Heavy-Duty Vehicle Smoke and Tampering Inspectlon Program (HDVIP) for diesel and gasoline fueled intrastate and interstate vehicles. This bill requires the ARB to design and jointly administer this HDVIP in conjunction with the California Highway Patrol (CHP). SB 1997 also provided for the establishment of an Ad Hoc Advisory Committee, comprised of representatives from the ARB, CHP, Engine Manufacturer's Association (EWA), California Trucking Association (CTA), and the South Coast Air Quality Management District (SCAQMD), to work cooperatively towards developing inspection and enforcement procedures for the HDVIP. SB 1997 authorizes the ARB to issue citations and assess civil penalties up to $1500 per day against owners of vehicles failing the prescribed test procedures. An additional $300 penalty is assessed with each citation Issued under the provisions of Assembly Bill 1107 of 1989. These latter monies are used for research and development of clean dlesel fuels. Vehicle owners, who fall to clear citations, may have their vehlcle placed out of service (placed in a storage yard) until the vehlcle is repaired and penalties are paid. Vehicles with a gross vehicle weight of 6000 pounds or more are subject to inspection. Inspections will be conducted at CHP inspection and weight enforcement terminals, random roadside locations and public and prlvate fleet locations statewide.

BACKGROUND

Numerous urban areas throughout the nation have adopted In-use motor vehlcle emissions inspection and maintenance (I/M) programs. These I/M programs are adopted, under the mandates of the federal Clean Air Act, to combat excessive emissions in an effort to achieve national ambient air quality standards (NAAQS). Under I/M programs, vehicles typically undergo a tailpipe emissions test and/or an underhood inspection aimed at detecting tampering or malfunctioning emission control systems. Vehicles which fail the prescribed test procedures are required to be repaired to comply with the applicable test standards. Typically, I/M programs are enforced through vehlcle registration while some programs utilize a compliance sticker onforcement process.

California has had an operational I/M program slnce March of 1984 in its major urban areas. This I/M program, referred to as "Smog Check', is a decentralized biennial program which targets gasoline powered vehicles. Its test procedure features-an underhood tampering inspection, functional

inspections of selected emission control components and a tailpipe emissions check. This program has demonstrated its initial effectiveness by reducing light-duty vehicle emissions by 12.32, 9.82, and 3.92 for HC, CO, and NOx respectively (5). SB 1997 authorized numerous enhancements to the Smog Check Program which should result in emissions reductions of approximately 282, 272, and 122 for HC, CO, and NOx respectively by the mid-1990's (6). These projected benefits indicate that this program will remain an effective abatement tool used to combat excess in-use motor vehicle emissions resulting from tampering and malmaintenance.

Nationwide, there are very few inspection programs that target excess emissions from heavy-duty diesel fueled vehicles. Heavy-duty diesel vehicles are commonly malmaintained or tampered with resulting in high emissions. In California, it is estimated that 45 tons per day of HC, 69 tons per day of PM, and 32 tons per day of NOx excess emissions result from tampering and malmaintenance of heavy-duty diesel vehicles. These emissions account for 42%, 56%, and 6% of the heavy-duty diesel vehicle emissions inventory for HC, PM, and NOx respectively (7).

The primary rationale for excluding diesel fueled vehicles from I/M programs centers around the difficulty of designing a test procedure which is simple and effective, Most diesel engine emission control systems are unique compared to those found on gasoline engines. Diesel engine emission control systems are typically internal to the engine and its components thus cannot be readily observed in an underhood inspection. Additionally, the traditional idle tailpipe emissions test used to detect HC and CO for gasoline engines is not effective for diesel engines because diesel engines typically produce low emissions under an idle operating condition. Unlike gasoline engines, diesel engines are designed to operate at non-stoichiometric air-fuel ratios (A:F) with excess air. These "excess air" air-fuel ratios are characteristic of low CO idle emissions. As a result, diesel vehicles have been excluded from traditional I/M programs because such programs would have limited effectiveness. One option available to I/M programs, is to add dynamometers and NOx analysis capabilities which would allow for effective diesel engine emissions testing. This option has not been pursued due to the high costs associated with these added capabilities. Another option, which has been adopted by numerous states, is utilizing visual observation to determine excessive diesel engine smoke levels. High diesel engine smoke levels is a valid indication of a malfunctioning engine typically caused by malmaintenance and/or tampering. Additionally, high smoke levels have a correlation with high PM and HC emission levels.

HEAVY-DUTY VEHICLE INSPECTION PROGRAM DEVELOPMENT

In order to develop an effective roadside inspection procedure (including applicable smoke opacity cutpoints and a civil penalty schedule) for identifying in-use heavy-duty diesel vehicles with excessive smoke emissions, ARB conducted two field studies (pilot programs) during the spring of 1989 and winter of 1990. The 1989 pilot program included a voluntary repair program aimed at quantifying the effectiveness of typical diesel engine repairs at reducing excessive smoke emissions. The following discusses those pilot programs and the subsequent public hearing for regulation adoption in detail.

INITIAL PILOT PROGRAM-In the spring of 1989, ARB conducted a voluntary pilot heavy-duty vehicle inspection program to: establish baseline smoke emission levels for in-use heavy-duty diesel vehicles, develop an effective smoke determination test procedure, and determine the cost-effectiveness of smoke reduction repairs. Approximately 600 trucks were tested at random and subjected to test procedures which featured acceleration and snap idle testing. ARB deployed field inspection teams consisting of two (2) field inspectors (personnel with automotive technology and motor vehicle emissions control credentials) and one (1) field engineer (personnel with automotive or mechanical engineering credentials) to each test site. The CHP deployed one (1) uniformed traffic officer to assist with vehicle selection and procurement. Tests were conducted at: the CHP Commercial Vehicle Inspection Facility (CYIF) located on Interstate 5 on the San Diego County/Orange County border in San Onofre, California; the CHP Platform Scale (PF) facility located on Interstate is on the San Diego County/Riverside County border in Rainbow, California; and at random roadside locations throughout the greater Los Angeles region.

The test procedure involved using an opacity (light extinction) meter and

a strip chart recorder to evaluate the smoke levels for snap idle tests. A visual evaluation of the smoke levels was also conducted for both the acceleration and snap idle tests. An underhood tampering inspection was also included in this test procedure. Both visual and smoke opacity metered methods were used for evaluation of the effectiveness of both methods. The opacity meter method featured the use of a Wager 650A smoke meter meeting industry standards as defined in Society of Automotive Engineers (SAE) specification J1243 (8,9). The visual smoke evaluation method, based on a visual emissions evaluation process which assigns numbers to smoke density (opacity) ranging from 0% (no visible smoke) to 100%(totally black smoke), was used by inspectors observing the exhaust plume. The inspectors, who are certified visual smoke evaluation readers In accordance with EPA (method 9) and ARB specifications, assigned a visual emissions smoke evaluation opacity value for each test performed.

This study concluded that while visible smoke evaluations ware in generally good agreement with the opacity meter readings, the variability of visual smoke evaluation makes opacity meter measurement the preferred method for vehicle testing. This variability results from attempting to observe the 'peak' smoke level that is instantaneous during the test process. The meter is able to effectively evaluate this 'peak" smoke level with a high level of accuracy and confidence.

During this pilot study, a 35% opacity standard was used. This standard was selected because the majority of heavy-duty diesel engine families certified since 1974 were certified at or less than 35%peak smoke opacity; which **is** far below the 50% peak opacity (EPA) certification standard (10). Additionally, the majority of the in-use heavy-duty diesel engines are 1974 and newer engines. Approximately 240 (40%) of the 602 vehicles tested in this pilot program failed when tested against this 35% opacity standard. **Of** the 602 vehicles tested, approximately 44% exceeded 40% opacity, 34% exceeded 55% opacity, and 22% exceeded 70% opacity (11).

VOLUNTARY REPAIR PROGRAM–ARB and EMA funded a voluntary repair program wherein failed vehicles were offered up to $1500 in authorized dealer performed repairs. The objectives **of** this study were to determine the reduction in smoke levels after repairs, the typical repairs made to reduce smoke and their costs, and the time required for repairs. This data was used to develop the civil penalty schedules and appropriate vehicle repair periods. Sixty-nine (69) trucks participated in this program and were repaired at an average cost of $600 per vehicle resulting in an average opacity reduction of 43.3% (12). This study identified the three primary causes of excessive smoke emissions as: improper air-fuel ratio control settings, fuel injection timing problems, and inadequate intake air (restricted air filters, etc.) (13,14). Figure 2 summarizes the data of this voluntary repair program and Figure 3 shows before and after repair peak smoke opacity for repaired trucks.

ENHANCED PILOT STUDY–In the winter of 1990, a second (enhanced) pilot study was conducted to gather supplemental data to validate proposed test procedures, opacity cutpoints and enforcement procedures. This study employed enhanced test procedures featuring the mounting of the opacity meter on the exhaust stack during acceleration testing. Data analyses from 310 vehicles in this study validated ARB'S proposal to use a snap idle test procedure and a 40% cutpoint for 1974 and newer engines and a 662 opacity cutpoint for pre 1974 engines for its enforcement program. (1974 and newer engines can be exempted from the 40% opacity standard to the 55% opacity standard if the engine manufacturer submits data demonstrating that the particular engine family had a federal peak smoke opacity certification standard in excess of 35%). The rationale for selecting the 40% opacity standard was based on the finding that snap acceleration smoke values are consistently 5% higher than the federal peak smoke opacity certification value as evidenced by data analysis from the pilot programs and engine manufacturer's certification data (15). Additionally, the 40% opacity standard allows for an 'error of commission' rate of less than 5% as mandated under the provisions of SB 1997. An 'error of commission' is defined as a failure of a properly functioning vehicle under the provisions of the HDVIP and Smog Check Program. This "error of commission" rate is premised on the fact that approximately 3% of the heavy-duty diesel engine families tested under the pilot programs were certified at federal peak smoke opacity levels between 35% and 50% peak opacity (16).

PUBLIC HEARING–A public hearing was held by the Board of the ARB in November 1990 for the adoption of the proposed regulations for the

implementation of the formal HDVIP (17). The proposed regulations were adopted and are being finalized pursuant to the reauirements of the California Administrative Procedures Act. ARB anticipates that these regulations will be promulgated during the spring or early summer of 1991 and enforcement testing will be implemented shortly thereafter.

HEAVY-DUTY VEHICLE INSPECTION PROGRAM ADMINISTRATION

PRE-ENFORCEMENT PROGRAM-In June of 1990, ARB commenced its pro-enforcement program. Under this program, nine inspection teams have been deployed statewide for the purpose of testing heavy-duty vehicles at CHP inspection and weight enforcement facilities, random roadside locations, and at public and private fleets. Operators of vehicles failing the proposed test procedures are issued a corrective letter (Notice of Non-Compliance) advising them of the pending enforcement program and asking for voluntary repairs to bring their vehicles into compliance. To supplement this pro-enforcement program, ARB launched an aggressive 'Outreach Program' aimed at educating the Operators, maintenance personnel and owners of heavy-duty truck and bus fleets as well as diagnostic and repair personnel and owners of heavy-duty vehicle repair facilities on the provisions of the HDVIP. Both the pre-enforcement and outreach programs have been well received by the heavy-duty vehicle industry. This has resulted in considerable voluntary compliance with HDVIP provisions as evidenced by a documented decrease in the field failure rate of heavy-duty vehicles when compared to the Pilot Programs failure rates.

ARB also has incorporated a 'Smoking Vehicle Complaint Program' into the HDVIP. Under this program, motorists report smoking trucks and buses to ARB. The complainant is asked to report the company name and license number of the vehicle and the date, time and location of the complaint. From this information, ARB staff prepares and sends a letter to the vehicle's registered owner advising him/her of the provisions of the HDVIP and requests that they voluntary bring the vehicle into compliance. ARB is also establishing a toll free 800 phone line for the HDVIP which will also serve as the 'smoking vehicle hotline'. ARB staff has experienced a high voluntary compliance rate with this 'Smoking Vehicle Complaint Program' to date.

PROPOSED ENFORCEMENT PROGRAM-Pending the promulgation of the HDVIP regulations, ARB will commence enforcement of the provisions of the HDVIP. As occurred under the pilot programs and pre-enforcement program, inspections will be conducted at CHP inspection and weight enforcement sites, random roadside locations, and at public and private fleet locations. Both intrastate (California licensed) and interstate (out of state licensed or apportioned) heavy-duty vehicles (trucks and busses in excess of 6000 pounds gross vehicle weight) will be inspected. Diesel fueled vehicles will be inspected for excessive smoke emissions and tampering with engine and emission controls. Gasoline fueled vehicles will be inspected for emission control systems tampering.

All inspections will be entered into ARB'S Heavy-Duty Vehicle Inspection (HEVI) computer system. This system will enable ARB staff to monitor inspections, track citations and civil penalty assessments, provide administrative adjudication for citations which are appealed, and evaluate the effectiveness of the HDVIP (18).

Citations will be issued to registered vehicle owners for vehicles failing the prescribed inspection procedures. A first level citation carries a civil penalty of $800; $500 of which is waived if the vehicle is repaired within a forty-five (45) day period and repair documentation is provided to ARB. Second and subsequent citations, within a one (1) year period, carry a civil penalty of $1800 and require the vehicle to be repaired within a forty-five (45) day period and undergo a mandatory post-repair test by ARB inspectors. Vehicle owners who fail to clear citations within the designated timeframes are subject to having their vehicles' removed from service by the CHP until all past penalties are paid and the vehicle is repaired. Vehicle owners may appeal citations through ARB'S proposed administrative hearing process as authorized by Senate Bill 1874 of 1990.

Public transit bus district fleets and school district bus fleets will be allowed to participate in ARB'S 'Voluntary Compliance Program' (VCP). Participants will be required to conduct routine smoke opacity and tampering inspections on their busses in accordance with VCP specifications. ARB inspectors will conduct periodic audits of maintenance records for these participants and test a random representative number of fleet vehicles

to ensure program compliance.

ARB estimates that 38,500 vehicles will be inspected during the first year of this program and 32,500 of these vehicles will be cited since the program will target smoking vehicles (19). Following two years of program operation, ARB, along with the CHP, will submit a report to the State Legislature on the effectiveness of the program. This report will include recommendations for program enhancements.

AIR QUALITY BENEFITS AND COST EFFECTIVENESS

The projected emission reduction benefits accruing from the implementation of this HDVIP are: 19 tpd of NOx (42 of the NOx emitted from these vehicles), 22 tpd of HC (272 of the HC emitted from these vehicles), and 32 tpd of PM (392 of the PM emitted from these vehicles) (20). Additionally, it is estimated that the HDVIP will reduce the number of on-road excessively smoking heavy-duty vehicles by 57% (21). The anticipated cost-effectiveness for this program is $0.44 per pound ($880 per ton) reduced for HC and NOx combined and $0.47 per pound ($940 per ton) reduced for PM. By comparison, the California Smog Check Program (I/M program) is estimated to have a cost-effectiveness of $2.30 per pound ($4600 per ton) reduced for HC and NOx (22).

CONCLUSIONS

1. The snap idle test procedure is an effective procedure for identifying excessively smoking heavy-duty diesel vehicles. This test procedure provides a good 'indication of a vehicle's smoke performance and has demonstrated a high confidence of repeatability.

2. The snap idle test procedure is effective for use at all inspection locales including CHP inspection and weight enforcement sites, random roadside locations, and fleets.

3. The proposed random roadside enforcement process (citation issuance and civil penalty assessments) is an effective tool for gaining voluntary compliance from heavy-duty vehicle operators and owners.

4. The random roadside design is more effective than a traditional registration enforced I/M program because all on road heavy-duty vehicles are targeted for enforcement while in operation.

5. The HDVIP, as proposed, is a cost-effective mobile source emission reduction strategy, as evidenced by its anticipated air quality benefits and cost-effectiveness, when compared to California's Smog Check Program and similar I/M programs.

6. The HDVIP is effective at addressing the public's concerns and complaints regarding excessively smoking on-road heavy-duty vehicles.

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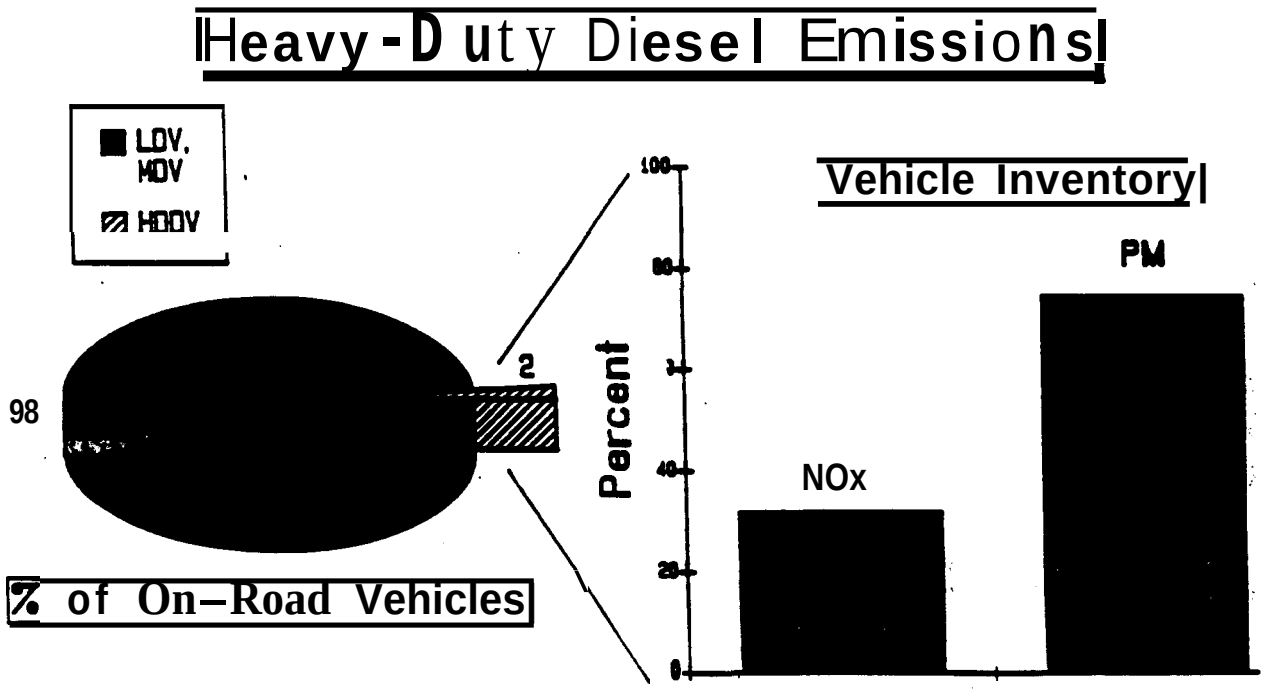

Figure 1. Heavy Duty Diesel Vehicle Emissions: their contribution to tho on-road rotor vehicle nitrogen oxide (NOx) and particulate matter (PM) emissions inventories and their representation in tho on-road motor vehicle fleet.

Pilot Program Vehicle Repair Sub-Program

- 69 Vehicles Tested and Repaired
- Repairs Partiaily Funded by ARB/EMA
- Average Time for Repair: 12 Days*
- Average Cost of Repair: $600
- Average Opacity Reduction 43.3%
- Common Repairs: SPL, Fuel Pump, Injectors

* Includes One-Half to One Day in Repair Shop

Figure 2. Voluntary Repair Program Data Summaries

Smoke Reductions After Repair
ARB Pilot Repair Program

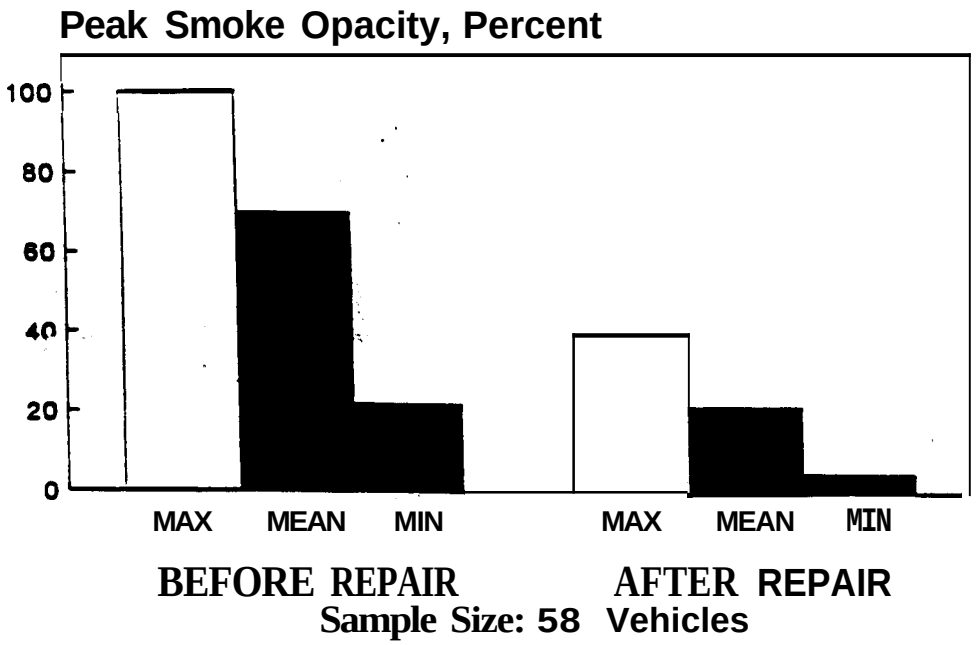

Figure 3. Smoke Reductions After Repair under the Voluntary Repair Program